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B. T. GALLOWAY, *Chief of Bureau.*

THE DISEASES OF GINSENG AND THEIR CONTROL.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., March 8, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 250 of the series of this Bureau a manuscript entitled "The Diseases of Ginseng and Their Control," by Prof. H. H. Whetzel, Plant Pathologist, Cornell University Agricultural Experiment Station, and Collaborator, Bureau of Plant Industry, and Mr. Joseph Rosenbaum, Special Agent, Bureau of Plant Industry.

Ginseng culture is actively pursued in many States and the growers have encountered an increasing number of diseases of late, thus creating a marked need and an active demand for information on the methods of control. To meet this need without duplication of effort and expenditure the Bureau of Plant Industry has arranged for the extension of the investigations in New York to other States and for the publication of the results for general distribution.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE DISEASES OF GINSENG AND THEIR CONTROL.

INTRODUCTION.

This bulletin represents the second attempt to bring together in concise form the knowledge of the diseases of the drug plant *Panax quinquifolium* L., commonly known as ginseng. The first publication of this nature was that by Van Hook [1] in 1904. Since that time there has accumulated a considerable body of new knowledge relative to the maladies of this crop, but more or less scattered in various bulletins and other publications. While further investigation of many of the diseases herein discussed is still needed, it is believed that the facts and conclusions presented in these pages represent our best knowledge of these to date.

Before taking up the discussion of specific diseases it seems desirable to point out some general considerations with respect to this crop which appear to have special significance as regards the diseases affecting it. Ginseng has but recently been brought under cultivation in this country. Twenty years doubtless cover all attempts at cultivation of any consequence in America. A closely related species has been cultivated for at least 200 years in Chosen (Korea) and Japan.

Ginseng is a native of the North Temperate Zone, finding most congenial conditions on woody hillsides and ravines covered with deciduous trees. This habitat indicates three factors favorable to its growth, i. e., shade, good soil drainage, and soil acidity. The failure of the grower to take all these factors into consideration when removing the ginseng from its natural habitat to his gardens has been primarily responsible for most of his losses. The necessity of shade was so evident that pioneer growers, almost without exception, took the hint and the shading of the beds has gone far toward perfection at the present time.

Not recognizing the tree roots of the forest as important factors in the drainage of the forest soils, the grower has seldom made the necessary tile drainage in his beds, depending usually upon the slope of the land to carry off excess rainfall. A frequent result has been heavy losses from root rots.

[1] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, 1904, pp. 163-186.

With little thought as to the chemical character of the forest soil to which the ginseng roots are accustomed he has made heavy applications of wood ashes or lime, bringing about an alkaline condition of his soil where an acid condition is required. The result has been an almost universal epidemic of the rust or fiber-rot caused by a fungus especially favored by an alkaline condition of the soil.

Another factor rarely considered by the grower, but one having a direct bearing upon the prevalence of disease among the plants, is crowding. In the forest the plants occur singly or in small colonies more or less widely separated from each other and protected from the contagious diseases of their neighbors by distance, tree trunks, and thickets and by the usual quiet air of the heavy forest depths. When brought under cultivation they are crowded together, touching each other on every hand. The old and diseased as well as the young and healthy roots are planted together side by side. There is nothing to prevent the ready spread of the spores or germs of any disease from one plant to another; hence, epidemics of Alternaria blight, Phytophthora mildew, etc., have occurred. Observations indicate that the cultivation of ginseng in small gardens will usually prove most profitable in the long run, but more space for each plant seems desirable.

In the following discussion the diseases described have been grouped under four types readily recognized by the grower, i. e., blights, wilts, galls, and rots. No attention has been paid to the cause of the disease in this classification. They are for the most part due to attacks of parasitic fungi. Nematode worms are responsible for the gall disease reported and the soft-rot appears to be due to the invasion of certain bacteria. Physiological derangements due to drought and the like appear to cause the papery leaf-spot.

Insect injuries, while occasionally occurring, are of too little importance to warrant description. Millipedes and snails often eat into the roots of young stems of the plants, but no very effective means of preventing this appears to be known. Moles occasionally cause injury by loosening the soil so as to cause a wilting of the plants and are believed by some growers to eat the roots at times. Traps appear to be the most effective means of combating this pest.

The data presented on each disease have been arranged under the four heads of History, Symptoms, Cause, and Control as representing those phases of most direct interest to the growers. Only such technical matter has been introduced as is deemed necessary for a clear understanding of the other facts presented.

SPECIFIC DISEASES OF GINSENG.

BLIGHTS.

ALTERNARIA BLIGHT.

Alternaria blight is the most common, widespread, and best known of the diseases of ginseng. Nevertheless, isolated gardens here and there appear to have thus far escaped the malady, though each growing season brings reports of the disease from new localities and every grower must expect sooner or later to meet this enemy of his crop. His success in combating the disease will depend more upon his accurate knowledge of the disease and the methods of controlling it than upon his peculiar location, the character of his soil, special methods of shading, etc. Notwithstanding the very general occurrence of this blight in all the ginseng-growing sections of the country and the repeated published descriptions of the disease, accompanied with suggestions for its control, many growers appear to be unacquainted with its symptoms, the nature of the fungus causing it, and the proper use of fungicides in combating the parasite.

History.—Just when the Alternaria blight first appeared in ginseng gardens can not be determined. Doubtless it has been present in some gardens since they were first planted. It is certain that the disease is a natural malady of the wild ginseng plant. The natural antipathy of the grower in the early days of the cultivation of this crop against admitting the presence of any disease in his stock, which was to be sold largely for planting new gardens, doubtless prevented to some extent the prompt reporting of this disease when it first appeared. It does not seem probable, however, that the disease was very common or destructive prior to 1904. Van Hook,[1] who first studied the diseases of ginseng, does not mention this disease in his bulletin published in the spring of 1904. The Alternaria leaf-spot described by him on pages 163 to 184 and shown in figures 39 and 40 is certainly not the disease now commonly known as Alternaria blight. Neither the spots nor the fungus figured are the same as the disease described herein. Had the blight been as common and destructive during 1902 and 1903 as it has been since that time Van Hook would certainly have observed it in some of his travels about the State of New York. For this reason the writers are inclined to the opinion that the very serious outbreaks of the disease in different gardens in 1904 mark the beginning of the history of this blight as a serious pest of cultivated ginseng.

During succeeding years the Alternaria blight has made its appearance in gardens all over the ginseng-growing regions of the United States and Canada. We have specimens and reports of the ravages

[1] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, June, 1904, pp. 163–186.

of the malady from as far west as Wisconsin and Kansas, south to Virginia, the Carolinas, and Tennessee, east to the Atlantic Ocean, and north to Michigan and Canada. This almost universal distribution of the disease is to be explained, in the writers' opinion, by the fact that it is a natural malady of the wild plant.

That the fungus causing the disease has been carried from garden to garden by visitors, the spores clinging to their clothing, seems more than probable. This would explain the very general dissemination of the parasite in a given locality or region. It will, however, hardly account for the appearance of the disease in widely separated regions or in isolated gardens far from the main centers of ginseng cultivation. It would seem but reasonable to hold that the fungus had found its way originally into each region or into isolated gardens on the wild plants that served as the original stock.

The history of the disease has been that where once established in a garden its complete eradication is quite out of the question. As long as thorough and systematic control measures are applied the disease may be held in check and its ravages reduced to a minimum. In some seasons weather conditions unfavorable to the fungus may serve to lead the grower into the notion that the disease has disappeared. The recurrence of favorable weather, however, soon disillusions him, and he finds his plants again going down before the onslaughts of the blight. The grower who has had one lesson should never need another. The grower who has never experienced a blight epidemic should equip himself to meet it; otherwise he will eventually suffer the consequences. (Pl. I, fig. 1.)

While the disease is certain to appear and disaster to follow if neglected, it can be controlled. The cause of the disease has been definitely demonstrated. A method of control has been worked out and repeatedly shown to be effective. The wise grower will accept proved facts and methods, will inform himself as to the nature and habits of the blight fungus, and will not be led astray by absurd theories and superstitious beliefs as to the nature of the disease and its control

Symptoms.—Contrary to the common opinion of the growers, the first symptoms of the disease are to be observed on the stems of the plants (Pl. II, fig. 1) instead of on the leaves (Pl. I, fig. 2).

After the plants are well up, a careful inspection of the gardens, especially where the blight was present the year before, will often reveal diseased stems here and there in the beds. These show dark-brown spots of some length on one side, usually just above the surface of the ground. (Pl. II, fig. 1.) Affected stems usually are not numerous and unless especially sought will be overlooked. The grower occasionally discovers these diseased stems, for they sometimes become so seriously affected that they rot off and break over. While

FIG. 1.—BED OF GINSENG PLANTS, SHOWING THE RESULT OF AN EPIDEMIC CAUSED BY ALTERNARIA BLIGHT.

FIG. 2.—LEAVES OF GINSENG, SHOWING ALTERNARIA LEAF-SPOT.

PARTS OF GINSENG PLANTS ATTACKED BY ALTERNARIA.

[Fig. 1.—Stems with dark-brown lesions. Fig. 2.—Plant attacked at base of leafstalks. Figs. 3, 4, and 5.—Seed heads.]

they seldom become numerous enough in a garden to cause serious loss from this trouble alone, they serve for the production of millions of the spores of the fungus which, scattered through the gardens, produce later the too well-known blighted leaves and tops.

The symptoms of the disease on the leaves are quite characteristic and generally well known. Spots of varying size, usually half an inch or more in diameter, appear on the leaves. (Pl. I, fig. 2.) At first water soaked, they gradually dry out, leaving a light papery center with a rather broad, rusty brown border. The spot may gradually spread and, uniting with other spots, involve the entire leaflet. The disease may also attack the tops at the point where the leaflets are attached to the leafstalks (Pl. III, fig. 1) or where these leafstalks arise at the top of the stem. (Pl. II, fig. 2.) The drooping of the leaflets from the end of the leafstalk and the drooping of the leafstalks from the top of the stem are symptoms also characteristic of mildew, but are readily distinguished from that disease by the velvety brown color of the stem and leafstalks at the point of attack. This velvety brown appearance of the parts affected with the Alternaria blight is due to the multitude of spores of the fungus covering the disease lesions.

The seed heads also are commonly affected. The green half-grown berries show brown, discolored spots; the little stem bearing the berry becomes brown and shrivels and the blasted berry falls. (Pl. II, figs. 3, 4, and 5.) This shelling of the berries, which may occur any time up to ripening, is often a puzzle to the grower.

There is so far no evidence that the disease ever directly attacks the roots of the plant. It is distinctly an aboveground disease. It affects the root indirectly by killing the tops and thus stunting or preventing further root growth. Roots of plants that have blighted badly one season appear never fully to recover from the shock, and even though their tops are protected from the disease the following seasons they never compare favorably with plants of the same age which have not suffered from the blight.

Cause. –The blight is caused by a fungus (*Alternaria panax* Whetzel), a minute parasitic plant that lives and grows within the tissues of the leaves, stems, and berries of the ginseng plant. It pushes its rootlike mycelium through the leaf or stem tissues of the ginseng, killing the living substances of the host and appropriating the foods and juices thus made available. From this mycelium it sends forth, to the outside, clusters of short, brown stalks, on the ends of which are produced the seedlike spores (fig. 1), singly or in short chains of two or more. Both the mycelium and the spores are very minute and can be distinguished only by the aid of a microscope. The spores are dark brown in color, with cross walls in both directions dividing

them into a number of small chambers or cells. Each cell of the spore is capable of germination, sending forth, when placed for an hour or so in water, a long sprout or germ tube (fig. 2). These germ tubes, if the spores be on a ginseng leaf or stem, penetrate the epidermis of the host and push through the tissues within, branching and forming the mycelium above described. It is only into the ginseng plant, however, that this germ tube is able to penetrate and develop, and this fungus is therefore never found causing a blight of other plants.

FIG. 1.—Chain of spores of *Alternaria panax* on the end of a spore stalk.

Alternaria panax is able to live as a parasite only upon the ginseng plant, and the very common opinion among growers that this fungus lives on weeds, potatoes, etc., and spreads from these to the ginseng is without any foundation in fact, so far as known. That this fungus is the genuine and only cause of the disease has been repeatedly proved by inoculations, that is, by placing spores of the Alternaria on the leaves and stems of healthy plants. The disease invariably appears in 4 to 10 days. That this fungus will not affect the potato, for example, has been shown by repeated failures to produce diseased spots by inoculating healthy potato leaves with the spores of the fungus.

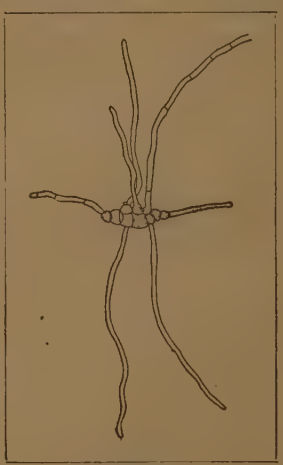


FIG. 2.—Germinating spore of *Alternaria panax*.

The manner in which the spores of the fungus first find their way into the gardens varies in different cases. Often the parasite doubtless has been brought in with wild plants from the woods, as it has been observed on ginseng plants in the woods. Sometimes it seems quite certain that the spores have been carried from diseased gardens to healthy ones on the clothes of persons visiting the gardens. That the fungus may be introduced with seed into a new garden is possible, but judging from careful observations extending over several years this is, to say the least, not at all common. We have never observed a single case of blight that could in any way be attributed to diseased seed. Furthermore, the disease is not at all common on seedlings, attacking them only under favorable conditions, when

there is an epidemic of the disease in older plants in adjoining beds. Other diseases of the seedlings are frequently confused with blight.

Having once been introduced into the gardens the seasonal habits of the parasite are as follows: The fungus passes the winter in old, dead, diseased stems of the previous season, the mycelium remaining alive but dormant in these old stems, much as the roots of the ginseng lie dormant in the soil. In the spring, when conditions become more favorable for the growth of the dormant ginseng roots and they begin to send up their stalks, the mycelium in the old stems also starts into growth, sending up new spore stalks on which a new crop of spores is quickly produced. We have observed this production of spores and have produced the disease in healthy plants by inoculation with them. It is quite possible that under favorable conditions the spores produced in the summer or fall may also pass the winter in a viable condition. They have been freely germinated when placed in water after having been kept dry in the laboratory for over three months. On the other hand, on the soil in the beds most of the spores produced through the summer probably germinate and die before winter. The new crop of spores produced from the mycelium in the old stems in the spring is doubtless the chief source of the first or primary infections.

The primary infections appear, as already described, on growing stems just above the surface of the ground. It is common to find a diseased stalk with the old stem still standing up beside it or lying at its base. It has been found easy to infect the new stalk as it comes through the ground with spores produced on the old stems. The fungus grows rather slowly on the stalk, so that the tops are usually well expanded before the spot has reached a size sufficient to attract attention. These spots on the stalk soon become covered with a velvety brown coat of spores, which are produced from the ends of the spore stalks that grow out from the mycelium in the diseased tissues. When these spores are ripe they break away from the spore stalks very readily and are carried through the garden by the slightest breeze. In this way they reach the leaves, falling upon the upper surface or into the crotches formed by the base of the leaflets or by the leaf stems at the top of the stalk. Here they lie inactive until a rain or heavy dew ensues. They then germinate and infect the leaf or leaf stems, as already described. Another crop of spores is now formed, especially on the diseased leaf stems. Spores are not usually produced abundantly on the spots on the leaves. This second crop of spores serves to infect the seed heads, causing the shelling of the berries. Spores are usually produced in great numbers on the diseased seed stalks and shriveled berries.

Many parasitic fungi pass the winter by means of a different kind of spore than that which is produced to spread the parasite through

the summer. This does not appear to be the habit of *Alternaria panax*, at least we have thus far never observed any winter spore form. The fungus apparently passes the winter as hibernating mycelium in the old, dead, diseased stems. The fungus is thus accounted for throughout the year. With these facts before us it should now be less difficult to understand its sudden appearance in the ginseng garden and the relation of weather, etc., to epidemics of the disease.

Ecology of the disease.—By ecology is here meant the relation of weather, location, shade, soil, mulch, etc., to the appearance and severity of the disease. It is a too common belief of growers that weather, soil, or some improper fertilizer is the direct cause of diseases in their crops. This is seldom true, certainly not in the case of Alternaria blight. These external factors, especially the weather, do influence to a marked extent the severity of the malady. The spores of the fungus not only require moisture in which to germinate, but that moisture must continue long enough on the leaves or stems so that the tender germ tubes may have time to penetrate the host plant and become established as mycelium in the tissues.

Just how much time is ordinarily required for this growth is not known, but experiments indicate that probably not less than 24 hours of cloudy, rainy weather or heavy dew are necessary. It requires from four to nine days for the diseased spots to make their appearance after infection. Cloudy, rainy weather is favorable to the rapid development of the spots after the fungus is established within the tissues. Heavy showers of short duration followed by bright sunny weather are not especially favorable to the blight. It is the cloudy, rainy periods continuing for a day or so that favor an epidemic of this disease.

The relation of temperature to the development of the disease has not been worked out. Growers generally hold that hot weather brings blight. It is true that the malady seems to develop most destructively during the hot months of July and August, but only when there is sufficient moisture. The seasons of 1907, 1908, and 1909 were generally hot and dry, and except in localities where there was a rainy period Alternaria blight caused relatively little loss. As is the case with many other parasitic fungi, it is quite possible that a drop in temperature accompanying a rainy period during the hot season is favorable to infection by *Alternaria panax*.

There has been much discussion by growers as to the relation of different types and amounts of shading to the blight. By some the question of mulch has been regarded as a controlling factor. We must confess that none of these theories appear to have any basis in fact. Our observations extending over a period of six years and a careful consideration of the data presented by growers convince us that shade and mulch have very little to do with the appearance and

severity of this disease in a garden. Location may play some part, though much less than is usually attributed to it. A garden so situated as to have good air drainage or ventilation may escape the disease to some extent, or occasionally, because the plants dry off more quickly, but the grower who depends upon his location instead of his sprayer for the control of the blight is doomed to lose sooner or later. The type of soil or kind of fertilizer used appears to be unimportant in regard to their relation to this disease.

Any of these factors—heat, shade, mulch, soil, fertilizer, etc.—is apt to be hit upon by the grower as a source of his misfortune when disease takes his crop, because of his lack of knowledge of the true nature of the malady, its causal organism, and the relation of external conditions to its development. Two factors appear to be of prime importance in the case of this disease: (1) The presence of the causal organism (*Alternaria panax*) and (2) the proper conditions as to moisture for its development.

Control.—While very satisfactory progress has been made in the control of this malady, there still remains much to be done in working out the details and perfecting the methods and means now employed for combating it.

The various means now employed in the control of the Alternaria blight are based upon one of three of the fundamental principles of plant-disease control and may be discussed as follows:

In most cases it is now too late to take measures to prevent the introduction of the fungus into the garden. It has already become established. In some gardens, more or less isolated, the disease has not yet appeared. In view of the strong probability that spores of the fungus are frequently carried from diseased gardens on the clothing of visitors it is highly important that growers having gardens that have never shown blight should exercise the greatest care in admitting persons to their inclosures. Neither the owner, workmen, or visitors should enter the garden in clothing, shoes included, which has recently been worn in gardens affected with the disease. Since the spores of the parasite retain their vitality for a long period, thorough brushing or even sterilization of the clothing after a visit to a disease-infested garden is imperative. The introduction of the fungus into new plantings with seed or roots is possible, but the evidence at hand indicates that this is not frequent.

Since the fungus is a natural enemy of the wild ginseng plant it may be easily introduced on diseased plants transplanted (top and all) from the woods. From the nature of the parasite it seems very probable that the fungus, if introduced with seed or roots, will be in bits of diseased stems or leaves mixed with the soil in which roots or seed are packed. Such soil should be so disposed of as to prevent its introduction into the new gardens. To guard against possible

spores or bits of infected stems getting into the soil with seed or roots, these may be dipped before planting for 10 or 15 minutes in a formalin solution, 2 parts in 100 parts of water. It must not be expected, however, that such measures will absolutely insure against the appearance of the fungus, and the ease with which it is carried from garden to garden makes certain its introduction sooner or later into even the most carefully guarded plantings. Other measures, which will be described later, must also be employed if losses from this pest are to be avoided.

The eradication of the fungus after it once becomes established in the garden is practically impossible. Sanitary measures, such as the removal and destruction of the diseased tops, the burning over of the beds in autumn, or the spraying of the surface with a strong copper sulphate solution will doubtless materially assist in holding the fungus in check. They alone can not be relied upon to prevent losses when conditions favorable to the parasite occur. Of the various sanitary measures thus employed, that of covering the beds with a layer of dry straw after the tops die down, and burning, is especially recommended. Where this is not feasible for any reason a copper sulphate solution (not Bordeaux mixture), 1 pound to 5 or 10 gallons of water, may be applied after the tops and mulch are removed. Enough should be applied to wet the soil to the depth of half an inch.

Protection of the plants from infection by the Alternaria fungus offers the most satisfactory means of controlling the malady. Proper location, so as to afford good ventilation, setting the plants farther apart, etc., all conduce to the rapid evaporation of moisture, and this, to a degree, protects the plants from infection, since the spores require continuous moisture for several hours to insure germination and the penetration of the host. These means are of relatively little value during a rainy period continuing for several days. By far the most efficient way of protecting the plants and thus controlling the disease is the practice of spraying, success in which depends upon strict adherence to the following rules:

(1) The spray mixture to be used must have proved its fungicidal efficiency against the spores of the fungus. Bordeaux mixture of the 3–3–50 formula has been proved both by careful laboratory tests and on the plants to be entirely effective against the parasite. The addition of Paris green or arsenate of lead is not necessary.

(2) The fungicide must not cause the burning of the plants when thoroughly applied at the effective dilution. A 10–10–50 mixture may be safely applied, but it is entirely unnecessary, since the 3–3–50 formula has been shown to prevent the germination of the Alternaria spores.

FIG. 1.—GINSENG PLANT ATTACKED BY ALTERNARIA AT THE TOP OF THE LEAFSTALK.

FIG. 2.—GINSENG PLANT, SHOWING A SYMPTOM OF THE PHYTOPHTHORA MILDEW KNOWN AS "BENDING-AT-THE-LOIN."

[The arrow indicates the point affected.]

FIG. 1.—LEAF-SPOT OF PHYTOPHTHORA MILDEW ON A GINSENG LEAF. (COMPARE WITH ALTERNARIA LEAF-SPOT, PL. I, FIG. 2.) FIG. 2.—ROOT-ROT LESION CAUSED BY PHYTOPHTHORA MILDEW. FIG. 3.—PAPERY LEAF-SPOT.

FIGS. 4, 5, AND 6.—GINSENG PLANTS, SHOWING ACROSTALAGMUS WILT.

(3) The fungicide must be thoroughly applied. All parts of the plants susceptible to infection—stems, leaves, and seed heads—must be covered and kept so. The development of the berries after blossoming exposes new surfaces not covered by earlier applications, and special spraying of the seed heads to prevent blasting and shelling of the berries is desirable. Since the first infections occur on the stems, it is desirable to spray very frequently when the plants are coming up and expanding. The fact that the plants in a given bed do not all come up at the same time makes frequent sprayings at this time highly desirable.

(4) Spraying should be done just before rainy periods, not after. The spores of the Alternaria fungus germinate only in water. The fungicide must be present on the plants when the condition favorable to the germination of the spores arrives. Once the fungus has established itself within the tissues of the ginseng neither the Bordeaux mixture nor any other fungicide can reach and destroy it. The time required for the diseased spots to appear after infection is from four days to a week. If the fungicide be applied directly after a rain in order that it may not wash off, infection will already have taken place and the spots will appear some days later in the leaves now coated with the poison. Spraying has often been condemned on account of such untimely application. For further data on spraying, the preparation of Bordeaux mixture, etc., see pages 37 to 40.

PHYTOPHTHORA MILDEW.

History.—Phytophthora mildew is a destructive disease of ginseng in Japan, where it was first reported by Hanai [1] in 1900, though Hori,[2] who first studied the disease and the fungus which causes it in 1904, states that it has long been known to Japanese ginseng growers. A year later, in the spring of 1905, Van Hook [3] received specimens of the disease from growers in Ohio and New York. Nearly every season since, the disease has been observed in gardens here and there in New York, Ohio, Pennsylvania, etc. In 1909 it was very destructive in some beds in a garden in New York, at least 20 per cent of the plants being destroyed, stem and root. As yet the disease has not become generally destructive in this country, but its general occurrence in ginseng gardens in many States indicates that at any time, under conditions especially favorable to it, it may develop as destructively here as in Japan. Hori [4] reports a loss of

[1] Hanai, I. On the Culture and Curing of the Idzumo Ginseng. Report, Central Agricultural Experiment Station, vol. 8, 1900, pp. 28-29. (In Japanese.)

[2] Hori, S. A Disease of the Japanese Ginseng Caused by Phytophthora Cactorum (Con. et Leb.) Schröt. Bulletin, Imperial Central Agricultural Experiment Station, Japan. vol. 1, 1907. pp. 153-162. (In English.)

[3] Van Hook, J. M. A Disease of Ginseng Due to Phytophthora. Special Crops, n. s., vol. 5, 1906, p. 94.

[4] Hori, S. Op. cit., p. 153.

$25,000 from this disease in one province of Japan in the spring of 1904. It appears to have been quite destructive in many gardens in Michigan in 1911. Our observations indicate that the disease is on the increase in the ginseng gardens of this country. The same disease affects forest-tree seedlings, having long been known as a serious pest in the seedling nurseries in Germany and in this country. It is very probable that the fungus causing this disease has been brought into the ginseng gardens on wild roots or in leaf mold from the woods.

Symptoms.—The symptoms of mildew, while in a way quite characteristic, are apt to be easily confused by the grower with those of the Alternaria blight. The most common sign of the malady is the drooping of the leaflets of one of the leaves from the end of the petiole. (Pl. III, fig. 2.) It is because of this symptom that the disease is known among Japanese growers as "Koshi-ore" (bending at the loins) or "Koshi-nae" (paralysis of the loins). An almost equally striking effect of the disease is the killing of the bases of the leafstalks where they join the stem, causing the leaves to droop and hang dead about the stem. Both these types of lesion may be produced by the Alternaria blight fungus, in which case, however, the diseased parts are covered by a brown felt of spores. (See page 11.) The mildew lesions may at first show an almost indiscernible silvery white coating of the spores of the causal fungus, but this soon disappears and the surface of the diseased parts becomes soft and slimy, especially if wet weather continues. The affected portions of the stem and leafstalks have a water-soaked appearance, strikingly different from the dry, brown canker effect of the Alternaria blight. The mildew also produces large spots on the leaves (Pl. IV, fig. 1), similar in form and size to those of the Alternaria blight, but strikingly different in color. At first these spots appear dark green and water soaked, quite like those of the blight in the early stages, but soon the center of the spot becomes white, the margins remaining a dark water-soaked green. There is no rusty brown discoloration of the margins of the spots as in the blight. (Compare Pl. I, fig. 2, and Pl. IV, fig. 1.) If cloudy, rainy weather continues, the disease extends rapidly down the stem and involves the root, causing it to rot. (Pl. IV, fig. 2.) Observations in the gardens show that the roots of plants, the tops of which are killed by the mildew, invariably rot unless promptly removed and dried. The Phytophthora mildew is thus seen to be one of the few diseases of ginseng which directly affect both tops and roots. The white-rot, described later, is another.

Cause.—The mildew is caused by *Phytophthora cactorum* (Con. and Leb.) Schröt., a fungus very similar to but not the same as the one causing the late-blight of potatoes. Conidia, or short-lived spores, are produced in great abundance in the spring on the affected stems

of the first plants to be attacked and are carried to healthy plants by the wind, splashing raindrops, and possibly also by insects. Thus, the fungus spreads through the beds from plant to plant.

The chief points of attack are where the leaflets are attached to the leafstalk and where the leafstalks are attached to the main stem. In these crotches water is retained for a longer time than elsewhere on the plant, thus affording better conditions for the germination of the conidia of the fungus. As the stem dies there is formed within it great numbers of microscopic resting spores, or oospores, which pass the winter in a dormant condition, germinating in the spring and forming conidia which are carried to some of the ginseng plants as they come up, thus starting the disease anew. The injury to the plant is affected by the rootlike mycelium of the fungus, which spreads through the tissues of stem, leaf, and root, secreting a poison that kills the plant tissues, thus providing nourishment for the growth and development of the parasite.

Control.—It has been shown by experiments both in Japan and in this country that the mildew is readily controlled by spraying the plants with Bordeaux mixture. To be effective the fungicide must be applied very early, while the plants are coming up. The disease seems to be checked by the warm, dry weather of summer. It is distinctly an early-spring disease. Care must be exercised in early spraying, as there is danger of injury from spray mixtures applied just before frosts. (See page 39.) Bordeaux mixture of the strength used for Alternaria blight, about 3–3–50, will control this disease. Much may be done toward eradicating the mildew from the gardens by the prompt removal of diseased plants from the beds, for, as already pointed out, it is in these diseased stems that the oospores of the fungus pass the winter. The roots should be dug and dried before the fungus has time to work down the stem and rot them.

VERMICULARIA STEM ANTHRACNOSE.

History.—Reed[1] reports Vermicularia stem anthracnose as the first disease to make its appearance in the spring in the ginseng gardens of Missouri, usually appearing about 30 days after the plants are up. What appears to be the same disease has been found on plants received from Tennessee and Virginia. It is not regarded as directly very destructive. Many plants are attacked but few killed, the greatest loss being in the destruction of the seed crop. The lesions are said also to afford entrance for a wilt fungus.

Symptoms.—The symptoms of this anthracnose, according to Reed, are the appearance of numerous black scars on the stems of the plants. These spots gradually spread, sometimes encircling the stems. The

[1] Reed, H. S. Three Fungous Diseases of the Cultivated Ginseng. Bulletin 69, Missouri Agricultural College Experiment Station, 1905, pp. 46–48 and 56–57.

first indication of the malady is the turning brown of one leaflet after another, the disease spreading from these down the petiole to the main stalk. In some cases the lesion encircles the stem, causing it to break over. The lesions are covered with the minute black pimple-like fruit bodies of the fungus.

Cause.—The fungus *Vermicularia dematium* (Pers.) Fr. is regarded by Reed as the cause of this disease. Our own observations in New York and other Northern States indicate that it is only a saprophyte, usually appearing on stems late in the season after they have been injured or killed from some other cause. The fungus is very common on stems killed by the Alternaria blight. Specimens of plants affected with this disease from Missouri and examined by us have always shown the presence of the Alternaria-blight fungus. This, together with the fact that Reed reports no inoculation experiments with the Vermicularia, indicates that he may have overlooked the true cause of the malady which he had under observation.

Control.—The disease was found to be readily controlled by spraying with Bordeaux mixture early, about three weeks after the plants came up, repeating this every three weeks until August 1. The removal and destruction of diseased stalks in the autumn are also to be recommended. In short, the methods of control already prescribed for the Alternaria blight will be found effective against this disease.

PESTALOZZIA LEAF ANTHRACNOSE.

History.—Pestalozzia leaf anthracnose has been reported only from Missouri by Reed [1] in 1905. It is said to be very destructive to young plants in that State. So far it has never been recognized in other ginseng-growing sections.

Symptoms.—This anthracnose attacks the base of the leaves and flower stalks, covering them with a black velvety growth and causing them to die and fall. These symptoms are very similar to those of the Alternaria blight when it attacks these parts of the plant.

Cause.—Reed found the fungus *Pestalozzia funerea* Desm. associated with these lesions and concluded that the fungus is parasitic and the cause of the disease.

Control.—Spraying with Bordeaux mixture is said to control the malady.

PAPERY LEAF-SPOT.

History.—Papery leaf-spot is observed more or less commonly every year, especially in dry seasons. During the past three years, which have been exceptionally dry in many sections, growers have sent in many specimens of plants affected with the papery leaf-spot.

[1] Reed, H. S. Three Fungous Diseases of the Cultivated Ginseng. Bulletin 69, Missouri Agricultural College Experiment Station, 1905, pp. 48, 58–59.

The disease has seldom been very destructive, usually only a few plants in certain places in the garden showing the trouble.

Symptoms.—The spots characteristic of this disease appear either between the veins or along the margins of the leaflet. At first small and circular, they rapidly enlarge and, coalescing with other spots, form large oblong or irregular-shaped areas (Pl. IV, fig. 3) of a papery texture, white or transparent, often with a yellowish tint. The last portion of the leaf to turn papery is that along the large veins and midrib which, retaining the green color for a long time, stands out in sharp contrast to the papery white areas. Growers often mistake the papery leaf-spot for the Alternaria blight, but the diseases are quite readily distinguished, as the spots of the former lack the rusty brown border of the latter.

Cause.—Bordeaux mixture is frequently held by growers to be responsible for this injury to the leaves, but the disease is equally common in unsprayed gardens. Our observations indicate that this spotting of the leaves results from an insufficient supply of water to the leaf tissues. The margins of the leaves and the areas between the main veins, being farthest from the water supply, are the first to suffer. As the tissues in these regions are gradually deprived of water the leaf green disappears and the tissues die and dry out, forming the spots characteristic of the disease. Of the various external factors which may bring about this lack of water supply, the following appear to be the most important: (1) Lack of rainfall (drought), the soil becoming so dry that the roots are unable to obtain sufficient moisture to supply the leaf surface exposed; (2) the presence in the beds of large tree roots, which exhaust the water supply to such an extent as to leave an insufficient amount for the ginseng; (3) insufficient shade, especially along the sides of the shack, permitting an abnormal drying out of the soil where thus exposed; (4) lack of fine feeding rootlets with their water-absorbing root hairs, due to attacks of fiber-rot or other diseases which destroy the rootlets. Under such conditions the papery leaf-spot may appear on plants in soil evidently having a sufficient water supply, but the roots being unable to absorb it the plant suffers exactly as though it was not present.

Control.—The measures to be suggested for the control of this disease are such as will correct the conditions which have given rise to the injury. These must first be determined in each case. Tile drainage will tend to equalize the moisture supply and protect the plants in dry seasons. Ginseng should not be planted in the region of large tree roots, i. e., in the feeding area of such roots. Provision should be made for the irrigation of the beds in excessively dry seasons. Injury to the absorbing rootlets should be prevented by proper treatment of the soil and roots where fiber-rot occurs. (See p. 31.)

INJURY CAUSED BY COLD FOLLOWING THE USE OF BORDEAUX MIXTURE.

History.—This injury was first observed by Whetzel[1] in New York during May and June, 1907. It was also reported during that spring from other States. Nine gardens were personally visited and the disease found to be quite destructive. One garden showed 20 per cent of the plants badly injured or killed; another 30 per cent. Reports from growers indicated losses ranging from a few plants in exposed places up to 50 per cent in some cases. Similar injury has been occasionally reported since that season, but it has never been serious.

Symptoms.—In all cases the injured plants appeared to have been affected shortly after they came through the soil. Fully expanded plants suffered but little. The injured portions of the plants appeared as though they had been dipped in scalding water. Some plants were killed back entirely to the ground. These had on a wet morning a dark-green water-soaked appearance and soon became soft, slimy, and rotten. When dry, the leaves became papery and brittle, crumbling readily between the fingers. In many cases the leaves alone suffered, the margins being burned and blackened. As the uninjured leaf tissue along the midribs grew and expanded, the leaves unfolded imperfectly, being tucked and wrinkled, with dead margins.

Where the stems were not killed outright a swelling with a russeting or checking of the epidermis appeared in a week or so. This injury is quite different from the curling or wrinkling of the leaves observed more or less commonly every spring and attributed to frost.

Cause.—From the fact that the disease has appeared only in gardens that were sprayed with Bordeaux mixture and only (to any extent) during abnormally cold weather, the conclusion seems inevitable that it is due to a combination of these two factors. The records show that the most serious injury occurred in those gardens where the Bordeaux mixture was applied during a day just prior to a heavy frost.

Control.—Little can be suggested by way of control, except that care be taken not to spray during extremely cold weather. Applications should be made during the forenoon in early spring on sunny days. Weather conditions especially favorable to this injury are likely to be rare. It is apparently the wetting of the plants just before a frost, rather than the fact that Bordeaux mixture was applied, that brings about the injury.

THE DAMPING-OFF OF SEEDLINGS.

History.—Ever since growers began to raise ginseng from the seed they have been more or less troubled with the loss of many of the

[1] Whetzel, H. H. Bordeaux Cold Injury of Ginseng during the Spring of 1907. Special Crops, n. s., vol. 6, 1907, pp. 184-187.

FIG. 1.—BED OF GINSENG PLANTS, SHOWING SEEDLINGS DESTROYED BY DAMPING-OFF WHERE THE DRIP FROM THE SHADING FALLS ON THE BEDS.

FIG. 2.—SEEDLINGS AFFECTED WITH DAMPING-OFF.

[Note the sharp angle at which they bend over. (Photographed by Van Hook.)]

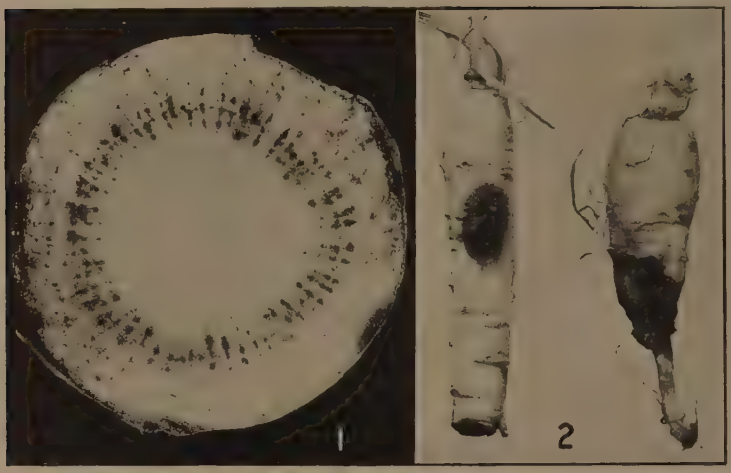


FIG. 1.—SECTION OF GINSENG ROOT, SHOWING A DISCOLORED RING OF SAP TUBES DUE TO ACROSTALAGMUS WILT. FIG. 2.—RUST SCAB ON OLD ROOTS.

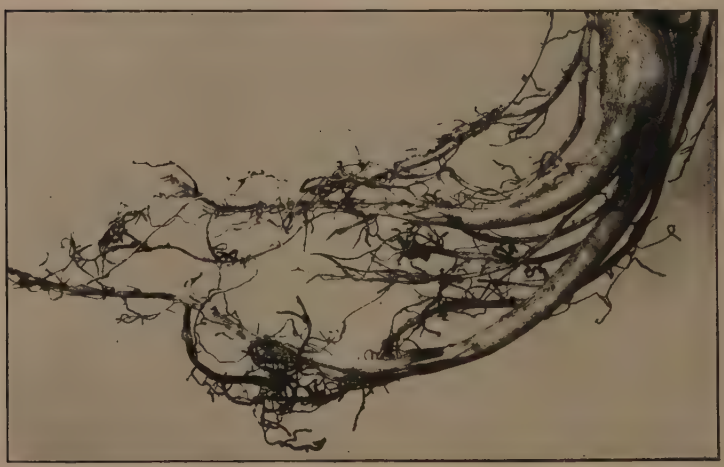


FIG. 3.—ROOTS OF GINSENG, SHOWING THE FIBERS OF OLDER PLANTS ROTTED BY RUST.

seedlings, especially in wet seasons. The earlier editions of Special Crops, a publication devoted to ginseng culture, are full of inquiries from growers which indicate that the trouble was caused by this damping-off of seedlings. This disease takes a heavy toll from the seedling beds. The little plants succumb quickly and often large areas in a bed are depopulated. Where the drip from the shading falls on the beds, thus affording moisture conditions especially favorable to the parasite causing the trouble, the losses are usually heavy. (Pl. V, fig. 1.) Half of the seedlings are frequently lost in a wet season.

Symptoms.—The wilting or drooping of seedlings may be due to several causes, and on careful examination the symptoms in each case are found to be different. In the case of damping-off, the tender stem just at the surface of the soil becomes soft and rotten and the top drops over, forming a sharp angle at the point of injury. (Pl. V, fig. 2.) If the stem droops in a smooth curve the trouble is usually to be looked for in the root, as in end-rot, described on page 28. Damping-off usually occurs in places where for some reason the soil is excessively wet, and as the causal fungus spreads from plant to plant through the soil several plants side by side are usually affected. No bronzing, yellowing, or reddening of the leaves accompanies the wilting from damping-off, as is the case in end-rot.

Cause.—The cause of damping-off of ginseng seedlings is, according to Van Hook,[1] the fungus Rhizoctonia. No extensive investigation of damping-off as it occurs in ginseng has been made. However, other fungi besides Rhizoctonia have been observed in damped-off seedlings, viz, the mildew fungus (*Phytophthora cactorum*) and the common damping-off fungus (*Phythium debaryanum*). Whatever is the causal organism, its destructiveness is conditioned directly upon the presence of excess moisture in the surface soil.

Control.—Various methods of preventing damping-off have been advocated by growers and others. Spraying the beds with various chemicals, especially dilute ammonia, has been held to be very effective. From the nature of the disease and the conditions which are known to favor it, two things are to be suggested: (1) The necessity of preventing excessive moisture in the seed beds, either by thorough drainage or by the exclusion of part or all of the rain, and (2) the planting of the seedlings in rows or drills, so that the soil between the rows may be loosened after each shower by hoe or other tool and thus, by drying out the soil, excessive moisture may be kept from the tender base of the stem of the seedling.

[1] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, 1904, pp. 174–175.

WILTS.

ACROSTALAGMUS WILT.

History.—Acrostalagmus wilt was one of the first diseases of ginseng to be carefully studied, having been quite fully described by Van Hook [1] in 1904. It appears to have been at that time the disease most commonly met with in ginseng gardens. Observations and records show that since that time it has been quite generally present each season in the gardens of New York, Pennsylvania, Michigan, Ohio, New Jersey, Wisconsin, Kentucky, Tennessee, etc. It has not been reported from Missouri or other States on the western border of the ginseng-growing region. A wilt was reported from Missouri by Reed in 1905, but from his description it is to be regarded as different from the disease here under consideration. While the wilt is very widely distributed and appears in most gardens to some extent every spring, it has never become epidemic and completely destructive like the blight. Whether under especially favorable conditions it might become a formidable malady remains to be seen. It appears to be one of those diseases which, like the white-rot, take a small annual toll that in the aggregate, however, amounts to considerable. The loss from this disease seldom exceeds 5 to 10 per cent, though beds have been examined in which at least 20 per cent of the plants were killed.

Symptoms.—This wilt makes its appearance rather early in the season, usually about the time the leaves become expanded. New infections do not appear to occur during the latter part of the growing season. The first evidence of the malady is the gradual wilting of the plants here and there in the beds, at first a mere drooping of the leaves, as on a hot day. The entire top soon wilts and dies. (Pl. IV, figs. 4, 5, 6.) If the plant is dug up, the roots usually will be found to appear perfectly healthy, with no external evidence of rot or other lesion. If the root be cut across, however, a part or all of the ring of sap tubes will be found to be yellow. (Pl. VI, fig. 1.) This yellowing of the sap tubes is a certain symptom of the wilt. If the roots are left in the ground, they eventually rot.

Cause.—The cause of this disease is a fungus (*Acrostalagmus* sp. ?), which enters the root probably through the old stem scars of previous seasons. Here in these scars the ends of the sap tubes which connected the roots with the stem are exposed and offer an open pathway for the entrance of the fungus into the root. Under the microscope the sap tubes of the neck and the root are seen to be filled with the matted threads of the fungus mycelium (fig. 3). These prevent the proper passage of water to the stem and the leaves above, and they

[1] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, 1904, pp. 168–174.

wilt. While the plant is still alive the fungus seems to be confined to the sap tubes, but as soon as the top wilts and dies the parasite probably spreads throughout the root, rotting it or at least admitting other rot organisms that complete the disintegration. The spores of the fungus are very minute and are formed on slender branched stalks which may develop over the surface of the rotted root or on the dead stems. (Fig. 4, *a*.) They probably find their way to the healthy plants through the movements of the soil water or the wind. The mycelium of the parasite forms minute black sclerotial masses (fig. 4, *b*), which appear to be a sort of resting condition and may serve to tide the fungus over from one season to the next in the soil.

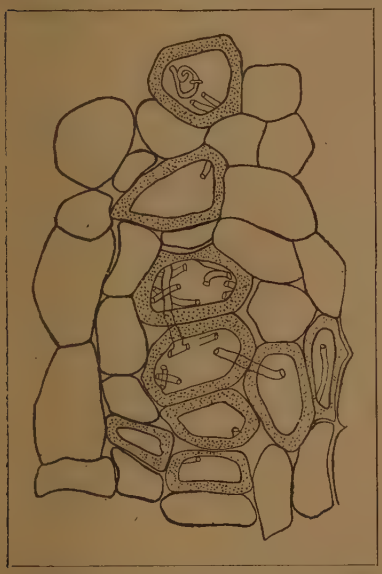


FIG. 3.—Section across sap tubes of root filled with mycelium of the Acrostalagmus wilt fungus. (After Van Hook).

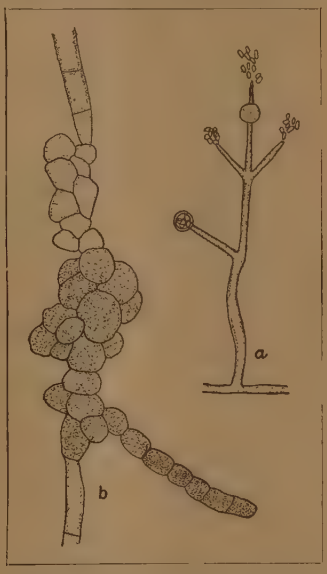


FIG. 4.—Acrostalagmus wilt: *a*, Spore-bearing stalk of the wilt fungus; *b*, sclerotial bodies formed in the mycelium.

Control.—Until more is known of the life habits of this wilt fungus little can be suggested as to its control. It is evident from what is already known that no method of spraying is likely to be effective. The prompt removal of affected plants, root and all, as soon as detected will do much to eradicate the parasite by preventing the formation of spores or the distribution through the soil of the resting sclerotia. Soil sterilization may prove effective. Wilted roots, if dug at once and dried, are but little injured. From extensive observations it appears possible that mulching with sawdust may favor the development of this malady.

FUSARIUM WILT.

History.—Fusarium wilt, while similar in some of its symptoms to the Acrostalagmus wilt, is evidently distinct from it. It was first reported by Reed [1] from Missouri in 1905, and, so far as we know, has never been found in ginseng in any other State since. According to Reed, this wilt is often very destructive, destroying whole plantations in a week. He regarded it as the most dangerous disease occurring in the ginseng gardens in Missouri.

Symptoms.—The Fusarium wilt appears somewhat later in the season (about July 1) than the Acrostalagmus wilt of the northeastern States. There is a gradual wilting of the leaves, but it is accompanied by a yellowing and dropping, which symptoms are wanting in the case of the wilt caused by Acrostalagmus. Both stem and root are invaded and the sap tubes are yellowed.

Cause.—This wilt is caused, according to Reed, by one of the wilt fungi, a Fusarium. It is thought to enter the stem first rather than the root and is believed to find its way in through lesions of the stem anthracnose, another disease, which attacks the stem earlier in the season near the base (p. 19). It produces its spores within the sap tubes. The fungus probably passes the winter in the old dead stems or on decaying vegetable matter in the soil, infecting healthy plants the next season.

Control.—Reed holds that no method of soil sterilization is likely to prove effective against the disease. The experience of certain growers in Missouri indicates that thorough spraying to prevent the stem anthracnose and other diseases through the lesions of which this parasite is supposed to enter will control the Fusarium wilt. The prompt removal and destruction of all diseased plants are to be recommended as profitable sanitary measures. Reed suggests the development of wilt-resistant varieties of ginseng, pointing out that there are always some plants in badly infested gardens that come through the epidemic uninjured. Seed from these should be saved and propagated separately.

GALLS.

NEMATODE ROOT-GALL.

History.—Ginseng is one of about 480 different plants [2] subject to nematode root-gall. Just when it was first observed on ginseng is not known, but early in the cultivation of this crop it was found by the growers when transplanting the roots, and Mr. George Stanton, the

[1] Reed, H. S. Three Fungous Diseases of the Cultivated Ginseng. Bulletin 69, Missouri Agricultural College Experiment Station, 1905, pp. 48–55, 59–65.

[2] Bessey, Ernst A. Root-Knot and Its Control. Bulletin 217, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1911, pp. 18, 72.

NOTE.—Growers who are especially interested in the nematode root-gall are urged to write to the Superintendent of Documents, Washington, D. C., for a copy of Dr. Bessey's bulletin on this subject; price 15 cents.

pioneer grower in New York, was accustomed to attribute all the ginseng ills of the early days to "nimetodes," as he called them. Van Hook [1] in 1904 was the first to give a careful description of these galls on ginseng. The evidence indicates that it is a widely distributed pest of this crop. Seriously infested gardens have been examined or reported from New York, Michigan, Ohio, and Wisconsin, as well as from the States in the southern portion of the ginseng-growing region. Van Hook inclines to the opinion that it is a natural pest of the wild ginseng and was thus introduced into the gardens. Bessey regards the parasite causing these galls as a native of the Tropics of the Old World which has gradually spread into the temperate regions, north and south. The injury to the crop is generally considered serious, as it greatly reduces the market value of the dry root and may destroy seedlings, but it is well known that older affected roots will continue to send up strong, healthy stalks, producing good crops of seed year after year.

Symptoms.—As pointed out, the tops seldom give evidence of the disease. It is only when the roots are dug up and exposed that the grower becomes aware of the injury from the nematodes. The roots, especially the fibers and smaller rootlets, are seen to be full of nodules or swellings of various sizes. (Pl. VII.) The galls are at first more or less smooth and white, becoming brownish and roughened with translucent watery spots as they become old, finally decaying. When affected rootlets die new roots are sent out, but are soon attacked by the parasite.

Cause.—These galls result from the attacks of the minute nematode worm (*Heterodera radicicola* (Greef) Müll.). It has been shown that this worm is a very common cause of root galls of many wild and cultivated plants, being most common and destructive in warm climates. The larvæ, which may live in moist soil for a time, bore into the roots and by their presence stimulate abnormal growth of the root tissues, resulting in the formation of the galls. These worms are very small and invisible to the naked eye, so that it would require from twelve to fifteen thousand of them end to end to span an inch. There are males and females, but the former die shortly after fertilizing the females, which then swell to a globose form, becoming filled with eggs. The eggs are laid within the tissues of the root or in the soil, where they soon hatch and develop the larval stage again. Those in the root shortly find their way into the soil by the disintegration of the gall or by boring directly out. After moving about in the soil for a time they penetrate into healthy roots and again set up the disease. The complete life cycle may take place within four weeks, or longer, depending upon the temperature of the

[1] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, 1904, pp. 176–181.

soil. In the cold soils of the North fewer generations of the worms develop than in the warmer soils and longer seasons of the South. The worms pass the winter either as larvæ in the soil or in the galls themselves as nearly mature females filled with eggs.

Control.—The frequent statement that thorough freezing of the soil of the ginseng bed will rid it of the nematodes is now known to be untrue. The following suggestions as to possibly effective means of control are the best that can be made at present. The roots should be dug in the fall, the galls cut away as much as possible, the roots dipped for 10 minutes into a solution of formaldehyde, using 1 part of the formalin solution to 100 parts of water. This is to kill the eggs and larvæ that may adhere to the roots. Replant in a soil in which ginseng has not been grown or treat the soil of the old beds with formalin, as explained on pages 40–41, before resetting the roots. To prevent the infection of the healthy roots, care should be exercised to prevent the transfer of infested soil from bed to bed. Tools used in infested beds should be disinfected by dipping in the formaldehyde solution before using in clean soil. These worms are easily killed by drying the soil, so that repeated stirring and drying of the soil during the summer might greatly reduce the number of worms in badly infested beds. The selection of gall-free roots, occasionally found in badly infested beds, is to be recommended for propagation, in the hope of obtaining a strain of ginseng resistant to the attacks of the worms.

ROTS.

RUST (FIBER-ROT, END-ROT).

History.—Rust (fiber-rot, end-rot) was first observed in the ginseng gardens of New York by Van Hook[1] in 1904. He describes it only on seedlings, giving it the name of "end-rot" because of the characteristic rotting away of the taproot. (Pl. VIII, fig. 1.) During 1908 and 1909[2] the disease was very destructive to seedlings throughout the ginseng gardens of the East. During these same years and even earlier, growers had complained of a disease of the older roots to which they gave the name of "rust." This disease was investigated at the Cornell station during the seasons of 1909[3] and 1910[4] and the conclusion reached was that it is but another form of the end-rot of seedlings. From an examination of many gardens in the principal ginseng-growing States during the seasons

[1] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, 1904, p. 176.

[2] Whetzel, H. H., and Rankin, W. H. End Rot or Fiber Rot of Seedlings. Special Crops, n. s., vol. 8, 1909, pp. 143–145.

[3] Whetzel, H. H., and Rankin, W. H. Fiber Rot or Rust of Ginseng Roots. Special Crops, n. s., vol. 8, 1909, pp. 146–147.

[4] Whetzel, H. H., and Osner, George. The Fiber Rot of Ginseng and its Control. Special Crops, n. s., vol. 9, 1910, pp. 411–416.

GINSENG ROOTS, SHOWING NEMATODE GALLS.

FIG. 1.—ROOTS OF SEEDLING PLANTS OF GINSENG, SHOWING THE EFFECT OF END-ROT.

FIG. 2.—BED OF GINSENG PLANTS, SHOWING THE EFFECT OF RUST ON LIMED AND UNLIMED SOILS.

[The limed soil is in the foreground, the unlimed at the back. The roots were of the same age and were set at the same time.]

of 1910 and 1911 and from specimens received from many others it is evident that this disease is, if anything, more widespread and destructive than the Alternaria blight. The average annual loss to the ginseng interests of the country from this disease must be not far from 25 per cent, and in many cases considerably in excess of this. Whole beds of seedlings are frequently rendered worthless and the growth of older plants so checked as to make their further cultivation unprofitable. A disease very similar to this, if not identical with it, is very destructive in the ginseng gardens of Chosen (Korea). It is known there as the red-rot.

Symptoms.—The symptoms of this disease vary considerably, depending upon the age of the root, the part attacked, the character of the weather, the severity of the infection, etc. In the case of seedlings the most striking symptoms during a dry season are a gradual change from the dark green of healthy leaves to a light-green shade, followed by premature coloring in shades of red and yellow, the leaflets finally withering and the stem wilting. Frequently the leaflets, instead of changing to a light green, take on a peculiar purple-bronze color. In wet weather the color changes are usually not so striking and the wilting is more sudden, the stem bending in a curve until the leaves (still green) touch the ground, differing strikingly from seedlings affected with damping-off, in which disease the stem bends at a sharp angle near the ground. (See Pl. V, fig. 2.) An examination of the roots of these seedlings will discover the fibers nearly or quite rotted away, with frequently only a bulblike crown bearing the prematurely and weakly developed bud. (Pl. VIII, fig. 1.) The rotted fibers are of a rusty brown or black color. In older plants the tops show similar symptoms in the way of premature coloration and wilting. The fibers of the root are more or less rotted (Pl. VI, fig. 3) and in severe cases entirely gone, leaving the root in a bare and stubby condition (Pl. VI, fig. 2) entirely without the absorbing apparatus necessary to supply the top with water. Both seedlings and older roots usually show brown scabby areas of dead skin, which may slough off, leaving the root more or less "pocked" or disfigured. Sometimes these rusty areas involve the entire surface of the root; sometimes the rusty scab is very superficial; in other cases it extends quite deeply into the flesh of the root. The diseased tissue is usually dry and spongy. However, the rust lesions seem to afford entrance to soft-rot organisms, which by penetrating deeply doubtless greatly increase the injury. This appears to be the case especially in wet seasons. We are inclined to the belief that the soft-rot (p. 32), so destructive in wet soils, is often, if not commonly, a secondary malady following the rust. While the absolute proof of the common cause of these different symptoms on seedlings and older roots has not yet been established, the evidence thus far

accumulated indicates that they are one and the same thing and may be, at least for the present, referred to as the "rust."

Cause.—While it can not be stated definitely that the fungus *Thielavia basicola* (B. and Br.) Zopf. is the cause of this disease (inoculation experiments not yet having been made), nevertheless the evidence points in that direction. Van Hook in 1904 reported the cause of the disease as unknown, but later in the same year at the Ohio experiment station he discovered [1] the fungus Thielavia on the roots of some ginseng seedlings affected with the end-rot. This fungus is a common parasite, causing a root-rot of numerous cultivated plants in this and other countries, tobacco,[2] violets, begonias, peas, and other legumes being among those most commonly attacked.[3] The fungus appears to be quite commonly associated with the lesions on the ginseng roots. This, together with its well-known parasitism on the roots of other plants, seems to warrant the assumption that it is the cause of the rust. This fungus is known to live in soils rich in humus, especially cultivated soils. It becomes parasitic under favorable conditions. It is now known that it is especially favored in its parasitism by an alkaline condition of the soil. In the natural forest habitat of the ginseng the soil is acid and the fungus does not appear to attack it.

During the past five or six years there has been a very general use of wood ashes and lime on the ginseng beds. This appears to account very largely for the increasing prevalence and destructiveness of rust. (Pl. VIII, fig. 2.) These substances make the soil alkaline. Another practice of growers which has doubtless gone far to increase the ravages from this parasite is the growing of seedlings on the same soil year after year or on beds from which a crop of mature roots has been dug. Under such a practice the soil becomes literally infested with the spores of the parasite. The fungus produces three kinds of spores, all of which have their share in the spread and perpetuation of the parasite. The long short-lived conidia are produced in great abundance on the diseased roots, especially in moist soil, and are probably carried by the currents of water in the soil or by earthworms, etc., to the healthy roots, there to bring about new infection. The dark-brown thick-walled resting spores are produced in great abundance on the lesions, especially in dry soils. These do not germinate until after a considerable period of rest. A third kind of spores, produced eight in a sac, are known as ascospores. These and the large brown resting spores evidently serve to winter the fungus in

[1] Selby, A. D. Tobacco Diseases and Tobacco Breeding. Bulletin 156, Ohio Agricultural Experiment Station, 1904, p. 96.

[2] Gilbert, W. W. The Root-Rot of Tobacco Caused by Thielavia Basicola. Bulletin 158, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, pp. 1–55.

[3] Duggar, B. M. Root-Rot of Tobacco, Violets, Peas, Lupines, etc. Fungous Diseases of Plants, 1909, pp. 210–213.

the soil, while the conidia are chiefly responsible for the spread of the fungus during the growing season.

While the fungus appears to be common in many cultivated soils, it is probably true that it has been introduced into new plantings on the roots purchased for setting the garden. It is spread through the garden in the soil on the shoes and tools of workmen. There is no evidence to indicate that it may be introduced with the seed. The injury to the root results from the growth within its tissues of the rootlike mycelium of the fungus. This mycelium originates from the germinating spore. It spreads through the tissues of the root, killing them and absorbing from them food for its own growth.

Control.—It has been found that in the case of tobacco seedlings the loss from the disease is greatly reduced by planting each year on new soil. While this is often feasible with ginseng seedlings, it could hardly be practiced with profit to the older roots, which should stand in the same soil for several years. Besides, many growers have a limited area in which to grow the crop, and the cost of moving the shading every season even for seed beds is not always practicable.

In view of the known relation of the parasite to alkaline soils the application of acid fertilizer is to be recommended. Briggs,[1] in working on the control of this disease in tobacco, found that the application of acid phosphate (treated rock) at the rate of about 1,000 pounds per acre very largely controlled the trouble. This is now quite generally used by ginseng growers and the results, while not uniformly satisfactory, have in many cases greatly reduced the disease. The fact that most gardens where the acid phosphate has been applied have previously received heavy coats of wood ashes or lime, or both, doubtless accounts for the failures reported. A chemical examination of the soil from a certain ginseng garden in Michigan last year showed that it was so alkaline from excessive applications of wood ashes that it would require 150 tons of acid phosphate per acre to neutralize it. Evidently the only thing to do in such a case is to abandon the soil for ginseng culture. Many growers have applied more than a ton of the acid phosphate per acre with good results. There appears to be little danger in overapplications of this in most gardens at present.

It has been found in Chosen (Korea) that the older roots affected with the rust may be largely cured in one season by dipping them in Bordeaux mixture for about 10 minutes and then, while still wet, planting them out in clean soil. At least one case is known in this country where such treatment has given marked results. Some growers report the rotting of roots following their treatment.

For seedling beds and old beds in which roots are to be reset, sterilization of the soil with steam or formalin is to be recommended.

[1] Briggs, L. J. The Field Treatment of Tobacco Root-Rot. Circular 7, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908, pp. 1–8.

(See p. 40.) Good results should not be expected if diseased or untreated roots are set in clean or sterilized soils. Even where sterilized, an application of acid phosphate is desirable.

Care should always be exercised to prevent the dissemination of the fungus in uncontaminated soils by the tools of workmen.

CORROSIVE-SUBLIMATE INJURY.

Among the substances early suggested for the treatment of ginseng roots affected with the rust was corrosive sublimate. This was doubtless due to the fact that growers, knowing its effectiveness against certain diseases of the potato tuber, notably the scab, hastily concluded that it would also be equally safe and efficient in the case of the rust on the roots of ginseng. Many growers tried the treatment during the autumn of 1910 with results quite uniformly disastrous, as shown at digging time in the autumn of 1911.

The strength of the solution commonly used appears to have been 1 ounce of the corrosive sublimate to 10 gallons of water, soaking the roots in this 10 minutes. A number of gardens were examined in which some of the roots in certain beds had received the above treatment, while other roots in the same bed had not been so treated. The treated roots uniformly showed serious injury. The skin of these roots had turned a reddish brown in color, not greatly unlike the rust but more uniformly covered with the discoloration. The fibers had all been destroyed and the beds set were not of normal size when compared with those of untreated roots growing in the next row in the same bed. Untreated roots were comparatively free from rusty discoloration, and the fibers were quite normal in length and numbers. It was evident that the corrosive-sublimate treatment alone was responsible for the injury.

SOFT-ROT.

History.—The soft-rot was one of the first diseases to attract the solicitous attention of the pioneer ginseng growers. The completeness of its destruction and the rapidity of its progress, especially in wet seasons or in wet places in the garden, soon induced the growers to bring it to the attention of pathologists. Van Hook[1] found it very destructive throughout the State of New York in 1903. It was also reported from other States. He says of it "In places the loss from this cause was enormous, and it is certainly safe to state that the greatest loss of ginseng in 1903 was from this rot." He records a case in which two-thirds of the plants in the bed were destroyed. The disease becomes most destructive during rainy periods in the summer, often in July and August. In 1909 the

[1] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, 1904, pp. 182–183.

GINSENG PLANT, SHOWING WILTING OF THE LEAVES CAUSED BY SOFT-ROT.

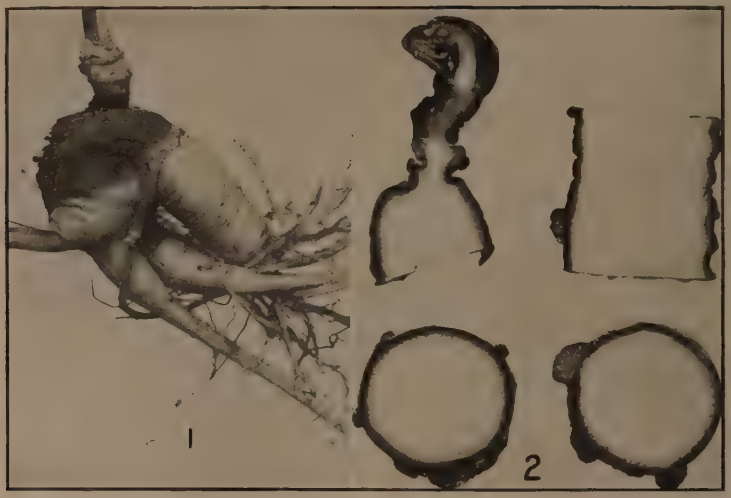


FIG. 1.—ROOT OF GINSENG, SHOWING SOFT-ROT STARTING AT THE CROWN. FIG. 2.—ROOT AND BUD OF GINSENG CUT OPEN, SHOWING BLACK-ROT.

FIG. 3.—ROOT AFFECTED WITH BLACK-ROT, SHOWING SCLEROTIA AND MUMMIED BUD.

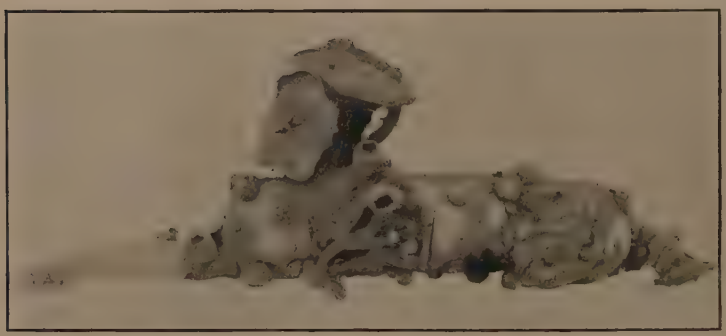


FIG. 4.—CUPLIKE FRUIT BODIES FORMED THE SECOND SEASON ON A ROOT AFFECTED WITH BLACK-ROT.

malady was very destructive in the ginseng-growing States west of New York, especially in Ohio and Indiana. That section suffered from excessive rainfall, while in the East it was very dry and little loss from the soft-rot was experienced. In 1911 the reverse conditions obtained, and again the soft-rot was the most destructive disease in New York and Pennsylvania. Past experience indicates that during wet seasons losses more or less serious are to be expected from this disease.

Symptoms.—The first indication of the soft-rot in the roots is a marked color change in the leaves of affected plants. This is usually not evident until the disease has made considerable progress in the root. The leaves appear rather thin and delicate, lack the dark rich-green color of healthy plants, and as the disease progresses in the root the leaves take on tinges of red and yellow as though maturing for autumn. In most cases the leaves remain erect until the complete rotting of the root; then the stem drops over or the leaves wilt about it. (Pl. IX.) The exact cause of this brilliant coloration of the leaves can not be explained at present. It appears to be a constant symptom of the soft-rot and is quite common in the case of other root rots, as pointed out in discussing the fiber-rot or rust.

On digging up plants the tops of which show a pale-green color, the first indication of the malady, the root will be found to show rot at some point. The rotting may begin at the crown (Pl. X, fig. 1) where the stem arises, the entire neck being involved, and spread from this downward, entirely destroying the root; or it may attack the fine fibers, gradually invading the larger rootlets and at last the main root itself (Pl. XI). If dug when the tops show the final stages of coloration, the root will be found to be a mass of soft, mushy consistency. It can scarcely be removed from the soil without breaking or crushing. The external examination of a partially diseased root shows a quite distinct line of demarkation between diseased and healthy tissue. The outer covering or skin of the root is for a long time intact, showing the watery brown appearance of the rotted flesh beneath, in sharp contrast to the white or pale yellow of the healthy portion. On cutting open a partially rotted root the tissues are found to be rather tough but watery and discolored. They soon become soft, like the rotting tissues of other vegetables attacked with soft-rots. The rotting roots give off a very strong offensive odor.

Cause.—The general characters of the diseased roots are so similar to those of the roots of other vegetables attacked with soft-rots that one is inclined to expect a similar cause here, namely bacteria. Certain bacteria have been found quite constantly associated with the rot in the ginseng roots. Preliminary inoculations made with these bacteria into healthy roots during the summer of 1911 resulted in the characteristic rotting of the roots, but only when an excessive amount

of water was applied to the soil. It has long been known that moisture is an important factor in the occurrence and severity of this disease. Van Hook was the first to point out that the soft-rot was most destructive where the soil was poorly drained, packed, and wet. That the disease is most common and destructive in wet seasons or in wet places in the garden and in heavy soils rather than in light, sandy ones, and that it is readily controlled by tile drainage, all show the marked influence of excessive moisture on the production of this rot.

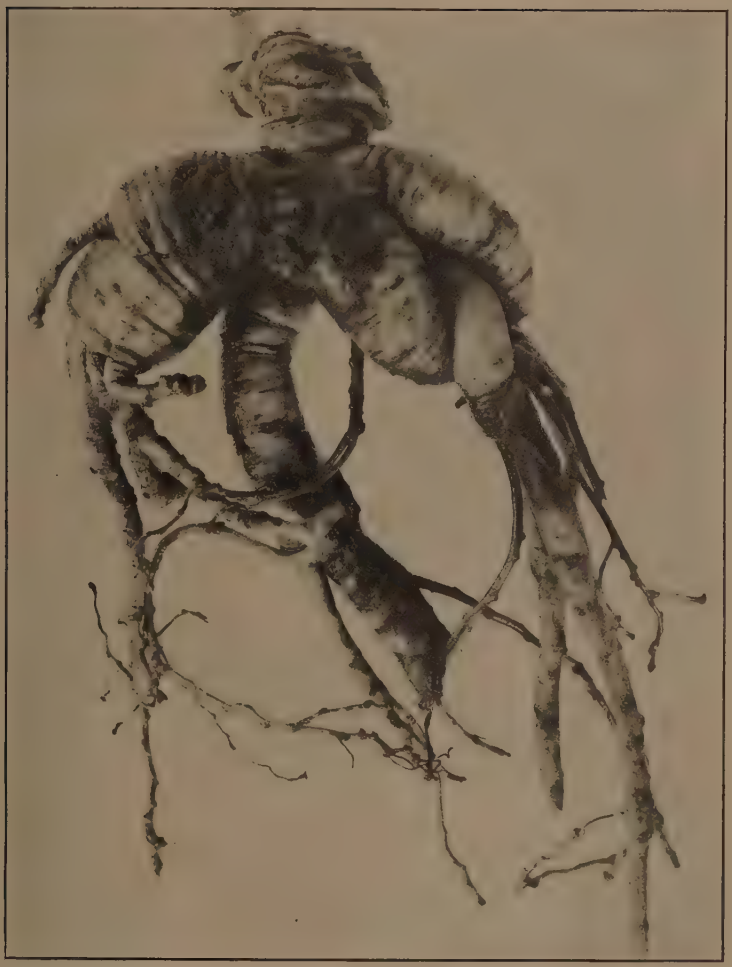
Control.—The proper lines along which the control of this disease is to be worked out have already been indicated. All soft-rotted roots should be removed as soon as discovered. This will do much toward reducing the causal organisms in the soil. All healthy roots should be taken up in the autumn and before transplanting a tile drain should be placed under the middle of each bed, as described on page 44. This will not only remove the excess water promptly, but will better equalize the water supply in the soil throughout the season. Where the disease has been very destructive in certain beds it may be desirable to treat the soil with steam or formalin, as described on pages 40–42.

SCLEROTINIA WHITE-ROT.

History.—The white-rot, or crown-rot, as it has sometimes been called,[1] is known to occur in most ginseng-growing regions. Specimens have been received or collected from many ginseng gardens in New York, Ontario, Ohio, Michigan, and Wisconsin. Although a widespread malady it is rarely destructive, usually only a plant here and there in a garden showing the disease. Occasionally, under especially favorable conditions (excessive moisture), it may become sufficiently destructive to attract the grower's attention. The loss from the disease in the total must be quite large. A few roots rotted in nearly every ginseng garden each year will in the aggregate mean a loss of many dollars to the ginseng industry. The disease is a common malady of many cultivated plants, especially truck-garden and greenhouse crops. It is known under various names according to the crop affected, e. g., the lettuce drop, the stem-rot of tobacco, the Sclerotinia disease of cucumbers, etc. This doubtless accounts for its common occurrence in ginseng beds, as many such beds have been made in old gardens.

Symptoms.—The white-rot usually appears in the growing plants during rainy periods in the spring or early summer. Affected plants wilt and sometimes fall over, owing to a rotting of the stem at its base, and usually involving the crown of the root.

[1] Rankin, W. H. Root Rots of Ginseng. Special Crops, n s., vol. 9, June, 1910, pp. 349-360.
Osner, G. A. Diseases of Ginseng Caused by Sclerotinia. [A paper presented before the Indiana Academy of Sciences in December, 1911.]



FIBERS AND SIDES OF THE MAIN ROOT OF A GINSENG PLANT ATTACKED BY SOFT-ROT.

FIG. 1.—ROOTS AND STEMS OF GINSENG AFFECTED WITH SCLEROTINIA WHITE-ROT.

[Note sclerotia on the side of root and within the stems.]

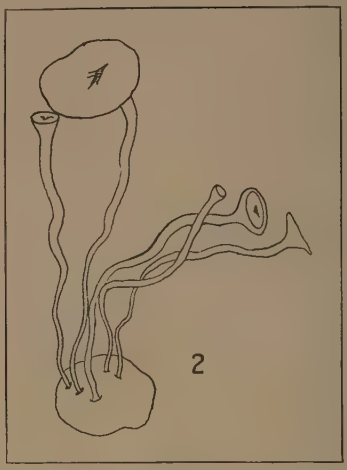


FIG. 2.—CUP-SHAPED FRUIT BODIES WHICH ARISE FROM SCLEROTIA OF THE WHITE-ROT FUNGUS.

FIG. 3.—LEAF INJURY TO A GINSENG PLANT CAUSED BY NITROGENOUS FERTILIZERS.

The diseased stem is bleached, soft, and often shows a white cottony felt over the surface. Large, black sclerotia or resting bodies of the fungus are often formed inside of the stem in the pith. (Pl. XII, fig. 1.) The disease has also been observed to attack the upper part of the stem. The point of attack in such cases is the place where the leaf stems are attached to the stalk. The petioles then rot and the leaves droop, but it is most commonly the root that is affected. In the spring the attack is usually through the base of the stem into the crown of the root, as already described. During the autumn rains roots are often infected through injured rootlets or fibers, the root rotting from the tip upward. The roots affected with this malady become soft and doughy, very watery, and tough but nonelastic. The rotted tissue remains white, hence the name, white-rot. The white mycelium of the fungus penetrates throughout the tissues of the root and grows out through the lenticles, forming bunches or tufts of cottony white felt, in which large black sclerotia rapidly develop (Pl. XII, fig. 1), like those of the stem already described. These sclerotia are diagnostic of this disease. They are hard tuberlike bodies, varying from the size of a grain of wheat to that of the end of the finger, black without, but white within. Diseased roots, if wrapped up and laid away in a place not too dry, will be covered with these bodies in a few days.

Cause.—The sclerotia-forming fungus found to be constantly associated with the white-rot appears to be *Sclerotinia libertiana* Fckl., a fungus which, as already pointed out, causes a rot of many garden plants. From the tuberlike sclerotia, as they lie buried in the soil in the spring, grow tiny cuplike fruit bodies (Pl. XII, fig. 2), in which the spores of the fungus are produced and shot in great numbers into the air. These spores, carried by the air currents in the garden, fall on the stems, and germinating in the moisture there send a rootlike germ tube into the tissues. This germ tube grows rapidly, forming a much-branched and ramifying mycelium, which soon involves not only the base of the stem but also the neck and the root, causing the rot and giving rise to the sclerotia already described. These sclerotia are the wintering tubers of the fungus and the only means by which it survives from one season to the next.

Control.—From the very nature of the disease it is evident that spraying can have but little effect in its control. Since excessive moisture in the soil and in the air of the shack favors the growth and development of the parasite, it is evident that tile drainage and efficient ventilation of the shack are the first measures to be taken. As the fungus survives from year to year by means of the sclerotia alone, it is plain that to destroy them or, better, to prevent their formation, is the second step to be taken to reduce the losses from this

disease. Stevens[1] has shown that this disease in lettuce may be entirely controlled by the prompt removal and destruction of diseased plants before sclerotia have had time to form. A similar practice in ginseng beds should prove effective. A daily inspection during the growing period in the spring and early summer should be made, expecially during rainy spells. All diseased plants, root and stem, should be carefully removed in a tight basket or bag and destroyed at once by burning them. The soil where the root was removed should be soaked with a solution of copper sulphate or Bordeaux mixture. Soil sterilization can not be depended upon to be effective against this disease.

SCLEROTINIA BLACK-ROT.

History.—Black-rot is doubtless a disease originally affecting wild ginseng. Growers who have seen the disease in the gardens declare that they have found black mummied roots in the woods. It was early known as a dangerous disease of cultivated ginseng. Van Hook[2] reports it in 1904 from a garden in New York, where it had occurred for at least six years. It is not a common disease, having been reported from only a few gardens in widely separated regions in New York, Michigan, and Wisconsin. It is usually not extensive in a garden, being confined to small areas in the beds, in which, however, all the roots are killed.[3] At least one grower is known to have abandoned the cultivation of ginseng chiefly on account of the ravages of black-rot.

Symptoms.—The first evidence of this disease is shown by circular bare spots in the beds where the plants have failed to come up in the spring. Roots dug from these areas, if affected with the black-rot, are coal black in color, devoid of fibers, but with the bud intact and black like the root. The surface of the root usually shows numerous black lumps (sclerotia) the size of a sweet-pea seed or smaller. (Pl. X, fig. 3.) If the root be cut open only the outer rind is found to be black, tough, and pliable. The center is white (Pl. X, fig. 2), spongy, and watery. There is no offensive odor as in soft-rot, but the natural flavor of the root is lost and it has become somewhat bitter, like quinine. During the first season after it becomes diseased, the root, if left in the soil, remains plump and firm. By the second season it blackens through, shrinks, and finally decays.

Cause.—The cause of this disease is a fungus (*Sclerotinia panacis* Rankin)[4] peculiar to ginseng. The outer rind of the root is first

[1] Stevens, F. L. A Serious Lettuce Disease. Bulletin 217, North Carolina Agricultural Experiment Station, pp. 16–21.

[2] Van Hook, J. M. Diseases of Ginseng. Bulletin 219, New York (Cornell) Agricultural Experiment Station, 1904, pp. 181–182.

[3] Rankin, W. H. Root Rots of Ginseng. Special Crops, n. s., vol. 9, June, 1910, p. 351.

[4] Rankin, W. H. Sclerotinia Panacis sp. nov., the Cause of a Root Rot of Ginseng. Phytopathology, vol. 2, 1912, pp. 28–31, pl. 3.

attacked, its structure being completely disorganized and rapidly replaced by a dense felt of the black mycelium of the fungus. Black tuberlike sclerotia arise from this mycelium. These resistant masses live through the summer and in the autumn produce mycelium which spreads through the soil and infects healthy roots. The second spring after their formation they give rise to cuplike fruit bodies (Pl. X, fig. 4) which expand at the surface of the soil and discharge their spores into the air. These spores are carried by the wind to other parts of the garden, where they germinate and infect healthy roots. At least two ways are thus known by which this fungus may be disseminated. A peculiarity of the parasite is that it develops and produces the disease only during cold weather, i. e., in late fall, winter, or early spring. No further spread of the disease occurs after the plants come up.

Control.—When once established, the fungus may remain in the soil for several years, even where ginseng has not been grown meantime. A sharp lookout should be kept for the disease in the fall when digging and in the spring where roots fail to come up in the beds. All the black roots in the diseased area should be promptly removed and destroyed and the soil thoroughly disinfected with steam or formalin. (See page 40.) All tools used in digging and the shoes of the workman as well as his hands should be thoroughly disinfected with the formalin solution before going to other parts of the bed. Every precaution should be taken to avoid scattering infested soil or bits of diseased roots in other parts of the garden. No experiments for the control of this disease have been made in the field, and the foregoing suggestions are the best that can be offered with our present knowledge of the disease.

THE SPRAYING OF GINSENG.

The spraying of ginseng is to be practiced for the prevention of only such diseases as primarily infect the parts of the plant above ground. Those diseases which are now known to be more or less controlled by spraying are Alternaria blight, Phytophthora mildew, Vermicularia stem anthracnose, and Pestalozzia leaf anthracnose.

Fungicides.—Various fungicides have been suggested from time to time for the control of the different diseases of ginseng. Alternaria blight in particular has called forth many remedies warranted to control the disease, but Bordeaux mixture stands out from past experience as the most reliable. It has been repeatedly demonstrated that Bordeaux mixture (3–3–50) alone will control the Alternaria blight; hence, the necessity of adding arsenate of lead to the mixture is scarcely apparent. The sticking qualities of the mixture itself are sufficient to prevent its being washed from the plants and the

general absence of insect pests on ginseng makes unnecessary the addition of an insecticide.

The preparation of Bordeaux mixture is a very simple process. Copper sulphate (blue vitriol), costing 5 to 10 cents per pound, good stone lime (or good hydrated lime), costing about a dollar a barrel, and water are the materials used. These ingredients are to be put together in the following proportions: Copper sulphate 3 pounds, lime 3 pounds, and water 50 gallons, expressed by the formula 3–3–50. Other proportions may be used for some diseases and under certain conditions. Larger proportions of copper sulphate and lime are never necessary. Copper is the active fungicidal agent. The lime is added to neutralize the caustic action of the copper sulphate, which would otherwise burn the leaves of the plant.

The mixture is prepared by dissolving 3 pounds of copper sulphate in 25 gallons of water, suspending the crystals in a cloth bag just beneath the surface of the water, as the dissolved copper settles quickly to the bottom. The lime milk is prepared by slaking 3 pounds of stone lime with hot water, adding the water slowly so that the lime may crumble into a fine powder. When completely slaked, i. e., entirely powdered, cold water to make 25 gallons is added.

To prepare any desired amount of the Bordeaux mixture, the two solutions are thoroughly stirred and equal quantities of each are poured together into a third vessel or into a sprayer tank. If it is desired to add an insecticide, it is added at this stage. Arsenate of lead may be used, at the rate of 2 pounds to 50 gallons, or Paris green, at the rate of 1 pound to 50 gallons. Paris green is likely to cause burning; the arsenate of lead will not. The stock solutions of lime and of copper must be kept in covered vessels and thoroughly stirred each time before pouring together. They are good until used.

Two strong solutions should never be poured together and diluted afterwards. The two solutions should never be poured together until ready to use. It is well to strain the mixture as it goes into the sprayer tank, to take out anything that might clog the nozzles. Neither tin nor iron vessels should be used in making the mixture. It will never be necessary to add "stickers" of any kind to the Bordeaux mixture. It will adhere sufficiently of itself and will not wash off in rains.

It is usually desirable to test the Bordeaux mixture, to be certain that enough lime has been added to neutralize the copper sulphate. The ferrocyanid test is the most convenient and accurate. An ounce of yellow prussiate of potash (potassium ferrocyanid) is put in a pint bottle which is then filled with water. This is poisonous and should be so labeled. Into the mouth of the bottle a cork is placed, from one side of which a V-shaped piece has been taken so as to provide a small opening into the bottle. After adding the lime milk to the copper

solution, a few drops of the ferrocyanid solution are put into the mixture. If it turns brown there is still some free copper sulphate, and more lime must be added.

Lime-sulphur has been tried on ginseng to a limited extent but usually with disastrous results. Germination tests with spores of Alternaria, on glass slips sprayed with lime-sulphur of different dilutions, indicate that it is not effective at strengths that can be safely applied to the ginseng plant. Ginseng appears to be very susceptible to injury from lime-sulphur.

Growers will save themselves much expense and loss by using tried and proven fungicides. If failure to control the disease results when Bordeaux mixture has been used, the difficulty is to be sought elsewhere than in the fungicide.

Time of application.—Failure to apply the fungicide at the proper time is one of the chief causes of failure. In general, the following rules will be found effective: (1) Begin spraying as soon as the plants come up, avoiding applications just before freezing weather.[1] (2) Spray frequently enough to cover all parts of the growing plant as they are exposed. More frequent sprayings will be necessary during the growing period of the tops in the spring than later in the summer. (3) Apply the spray mixtures always just ahead of the rains, not just after. The spores of the disease-inducing fungi germinate and their germ tubes penetrate the host plant only during rainy, cloudy periods. Watch the weather map. (4) Important periods in the development of the plant are also to be taken into consideration in spraying, viz, when the plants are coming up and expanding; when the leaves and stems have fully expanded; just before the blossoms begin to open; just as the berries begin to enlarge; just before the berries begin to color. Applications made at these times to the parts of the plants indicated are likely to be most effective.

Thoroughness of application.—A few thorough applications are far more effective than many poorly made. From three to five timely applications thoroughly done should be sufficient in most seasons. It is not necessary to spray the under sides of the leaves. The stems and seed heads, however, should be thoroughly covered on all sides. Thorough work can be done only with a nozzle giving a fine mist, driven on the plants with high pressure. No pressure of less than 50 pounds should be tolerated. A hundred pounds is better. No machine at present appears to be entirely satisfactory for the spraying of ginseng, though several are made which will answer the purpose.

The philosophy of spraying.—Spraying is generally done as a preventive of disease, seldom as a cure. This fact especially applies to ginseng. The fungicide must be applied to the leaves, stems, etc.,

[1] Whetzel, H. H. Bordeaux Cold Injury of Ginseng during the Spring of 1907. Special Crops, n. s., vol. 6, pp. 184–187.

before the arrival of the fungous spores, at least before they germinate and initiate the disease. The fungus must be killed before it has entered the tissues of the plant, where the fungicide can not reach it. Little is to be expected of applications made after the disease has made its appearance in the plants, except to prevent further infection of healthy ones.

SOIL STERILIZATION FOR GINSENG.

It is well known that soil on which the same crop has been grown successively for several seasons frequently becomes unproductive. That this decrease in productivity in many places is due in considerable degree to the multiplication of certain pathogenic organisms, fungi or bacteria, is generally accepted. Such soils are often said to be "sick." Notable instances of such sickness are the flax-sick and wheat-sick soils of the Northwest and the tobacco-sick and cotton-sick soils of the South. It is not surprising, therefore, that in view of the many diseases seen to affect the roots of the ginseng plant, ginseng-sick soils should also be found, especially since ginseng is a long-time crop, remaining permanently in the same soil for at least three or four years. This unproductiveness of soils is often attributed to causes such as the exhaustion of fertility and the production of poisonous secretions from the roots of the crop grown on the soil instead of to pathogenic organisms in the soil. At any rate, sterilization of crop-sick soils has often proved highly profitable, and from the nature of the diseases attacking ginseng roots and the favorable results thus far recorded in the sterilization of ginseng soils, much is to be expected from this treatment in the future.

One of the most efficient and satisfactory methods of renovating crop-sick soils is rotation of the crops grown upon it. Unfortunately, this is not usually practicable in the case of ginseng. Some growers are practicing a rotation with golden-seal in their ginseng beds. This rotation has not been tried extensively enough to warrant conclusions. Sterilization, therefore, remains as the most practical method at present of renovating old ginseng soils. Aside from the destruction of parasitic fungi, sterilization often appears to actually increase the availability of food substances in the soil, the result being a marked increase in the growth of the crop.

The most practicable methods of sterilizing ginseng soils appears to be by the use of either formaldehyde or steam.

Formaldehyde.—The sterilization of ginseng beds with formaldehyde should usually be undertaken in the autumn, though it may sometimes be done in the spring. Remove the roots from the beds, throwing the soil up loosely. The drier the soil the better. Sterilizing the soil in a wet season presents many difficulties, especially where formalin is used. The formalin (which is the formaldehyde gas

dissolved in water) of a 40 per cent strength is diluted in water at the rate of 1 part of formalin to 100 parts of water. If the soil is quite wet the proportion of water should be reduced accordingly. Remember that the water in the soil will dilute the formalin. The grower must here use his judgment. In many cases a dilution of 1 part of formalin to 50 parts of water may be best. This solution (1 part to 100) should be applied to the soil at about the rate of 1 gallon to the square foot; less, of course, if the soil be wet and the solution stronger. It is best applied by one man either through hose attached to large tank or with a large watering pot, another workman spading the soil over as the solution goes on. It should be

FIG. 5.—Apparatus for steam sterilizing soil by the inverted-pan method.

pointed out that all beds treated with formalin should be first tile-drained, and the soil should not be worked after treatment until the excess water is well drained off. As soon as the soil will work without puddling, it should be again thrown up loosely to permit the evaporation of the formaldehyde. Ten days or two weeks after treatment, several respadings of the soil having been made, the beds should be in shape for replanting.

Steam sterilization.—Where a good steam boiler is available, steam may be used very effectively. The inverted-pan method devised by Mr. A. D. Shamel, of the Bureau of Plant Industry, appears to be the most practicable for ginseng beds. The apparatus (fig. 5) for

ginseng beds of the usual width should consist of a galvanized-iron pan, 4 by 10 feet and 6 inches deep, which is inverted over the soil to be sterilized, the steam being admitted through a steam hose connection in the end or side of the pan. The sharp edges of the pan which are forced down into the soil prevent the escape of the steam. The pan is fitted with handles for moving, and should weigh not more than 400 pounds. The soil is prepared as for planting. All fertilizers are applied and worked in as desired. A few potatoes are buried at a depth of about a foot to gauge the degree of heat attained. These should be cooked when sterilization is completed. The steam should be kept at as high a pressure as possible, 80 to 100 pounds, and the treatment should be continued for one to two hours, depending upon the pressure maintained. This treatment will destroy not only all fungous spores but weed seeds as well.

RELATION OF FERTILIZERS TO DISEASES OF GINSENG.

It is not the intention here to discuss the use or value of different fertilizers for the production of increased yields of ginseng. It is desired only to call the attention of growers to a few facts in regard to the effect on certain diseases of this crop of some substances which may be applied to the soil as fertilizers. But relatively little is known concerning this subject even as regards crops much older and more extensively studied than ginseng. We shall call attention only to some points on which we seem to have a little light.

Lime.—Lime has been widely used by growers on their ginseng beds. Many beds have been examined in which lumps of lime were still to be seen in the soil the second season after it had been applied, so heavy was the application. From the natural acid character of the woodland soil in which ginseng grows in a wild state, lime would seem of doubtful value to the plant under cultivation. Disaster in the form of the root-rust or fiber-rot has almost invariably followed its use. An alkaline condition is very favorable to the development of *Thielavia basicola*, the fungus believed to cause this disease. Lime applied to the soil brings about this alkaline condition. Its use on ginseng soil is to be avoided.

Wood ashes.—On account of the high percentage of lime which wood ashes contain their action in relation to root-rust or fiber-rot is much the same as that of lime, and their use is dangerous.

Acid phosphate.—One of the constituents of most commercial fertilizers is acid phosphate, to be had in the form of treated rock, i. e., containing phosphorous treated with sulphuric acid. It may also be had in the form of acid-treated bone. Its effect upon the soil is to bring about an acid condition which is unfavorable to the rust fungus[1]

[1] Briggs, L. J. The Field Treatment of Tobacco Root-Rot. Circular 7, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908, pp. 6–8.

and apparently favorable to the growth of ginseng. Hence, the application of acid phosphate (treated rock) is one of the most efficient means of combating this disease. The amount to be applied will depend upon the previous treatment of the soil; that is, whether limed or fertilized with ashes, etc. From 1,000 to 2,000 pounds of acid phosphate per acre have given good results in many places.[1] Where the soil from repeated applications of lime or ashes has become very alkaline it may be very unprofitable to attempt to remedy contions by the use of acid phosphate. (See p. 31.) Where acid phosphate is used for this disease no nitrogen or potash is to be used with it.

Leaf mulch.—Very recently Mr. Frederick V. Coville, of the United States Department of Agriculture, has called our attention[2] to the fact that ordinary oak or maple leaves when freshly fallen contain a large proportion of acid which rapidly leaches out of the leaves with the rains of fall and winter. He has suggested the possibility of bringing about an acid condition of the ginseng beds by the use of a mulch of oak or maple leaves applied as soon as they fall in autumn and removed early in the spring before they can interfere with the coming up of the plants. Extensive experiments to test this suggestion are now under way, but no results can yet be reported.

Nitrogenous fertilizers.—An excessive use of nitrogenous fertilizers appears to be responsible very frequently for a serious leaf injury. (Pl.XII, fig. 3.) This injury has been many times observed and in certain places it was clear that heavy applications of nitrate of soda to the soil the previous autumn were responsible for it. In other cases the evidence carefully gathered and studied indicated that heavy applications of barnyard manure had produced the injury. Similar injury from the use of hen manure on the beds is reported. A light mulch of manure, even fresh manure, applied in the fall does not appear to be dangerous.

DRAINAGE OF GINSENG BEDS.

In a number of connections the necessity for artificial drainage in the cultivation of ginseng has been already pointed out. Drainage consists essentially in the removal of excess water from the soil in the root zone. When plants are growing naturally in the forest the excess water in the soil is removed by the roots of the trees and shrubs. Under cultivation some artificial means of removing this excess of water from the beds must be employed. The means best adapted for ginseng gardens is some type of underground channel. Open drains, usually the paths, are not efficient and are not to be

[1] Whetzel, H. H., and Osner, George. The Fiber Rot of Ginseng and its Control. Special crops, n. s., vol. 9, 1910, pp. 411–416.

[2] In a letter dated October 27, 1911.

depended on. Many materials may be used for these underdrains, but the ordinary hard-burned clay tiles have proved most effective and permanent. Cement tiles now coming into use are also very satisfactory.

Depth, frequency, and size of drains.—The drainage method must vary with the character of the soil, subsoil, and the character and amount of the rainfall. Since water percolates so much more readily through sand and gravel than through clay, drains should be placed much deeper in the former (3 to 4 feet) than the latter (1½ to 2 feet). The lines of tiles should be placed from 6 to 8 feet apart and where possible under the center of the bed. The size of the tiles depend upon the volume of water to be handled and upon the slope of the land or gradient. In general 3-inch tiles will be found satisfactory.

In the construction of a tile drain the grower should take special precaution in regard to a number of points. Some of these points are as follows: (1) So far as possible the drain should run with the slope of the land, the fall being as great as the nature of the land will permit having the gradient uniform. (2) The outlet should be well protected against the entrance of small animals. (3) The joints should be fairly close, a feature that can best be attained by the use of hexagonal tiles.

Effect of drainage.—The tile drain will not only remove the excess of water from the root zone and in this way make the roots less liable to the attacks of certain parasitic organisms, but will affect the roots in a number of other ways. Among the most important of these effects are the following: (1) It improves the aeration. This result comes from the granulating effect of the removal of the excess water, allowing a better circulation of air through the soil. The roots of plants require the oxygen of the air just as do man and other animals. Oxygen is also necessary for the growth of favorable soil organisms. (2) Drainage raises the average temperature of the soil. It is well known among growers that a wet soil is a late soil, while a well-drained soil is much earlier in attaining the temperature necessary for the germination and growth of plants. In other words good drainage lengthens the growing season. (3) Drainage will reduce heaving which results from the freezing of wet soils. In the opinion of many growers heaving is responsible for much injury to seedlings.

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